

UK Patent Application (19) GB (11) 2 063 592 A

(21) Application No 8035430

(22) Date of filing
4 Nov 1980

(30) Priority data

(31) 79/38627

(32) 7 Nov 1979

(33) United Kingdom (GB)

(43) Application published
3 Jun 1981

(51) INT CL³ B01F 13/08
H02J 1/00
H02P 8/00

(52) Domestic classification
H2H 22G 23G 25G EM

(56) Documents cited
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(58) Field of search

B1C

H2H

H2J

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(54) Magnetic stirrer and drive circuit

(57) In a magnetic stirrer, the stirring element is driven by an array of electromagnets (1,2,3,4) which are energised sequentially so as to create a rotating magnetic field. Energisation of the electromagnets is controlled by a solid state timer and associated logic circuitry allowing variation of the stirring speed. The electromagnets are energised by D.C. supplies through fast switching semi-conductor switches (Q1-Q4) whereby each electromagnet receives a square wave supply with peak current throughout the period it is energised.

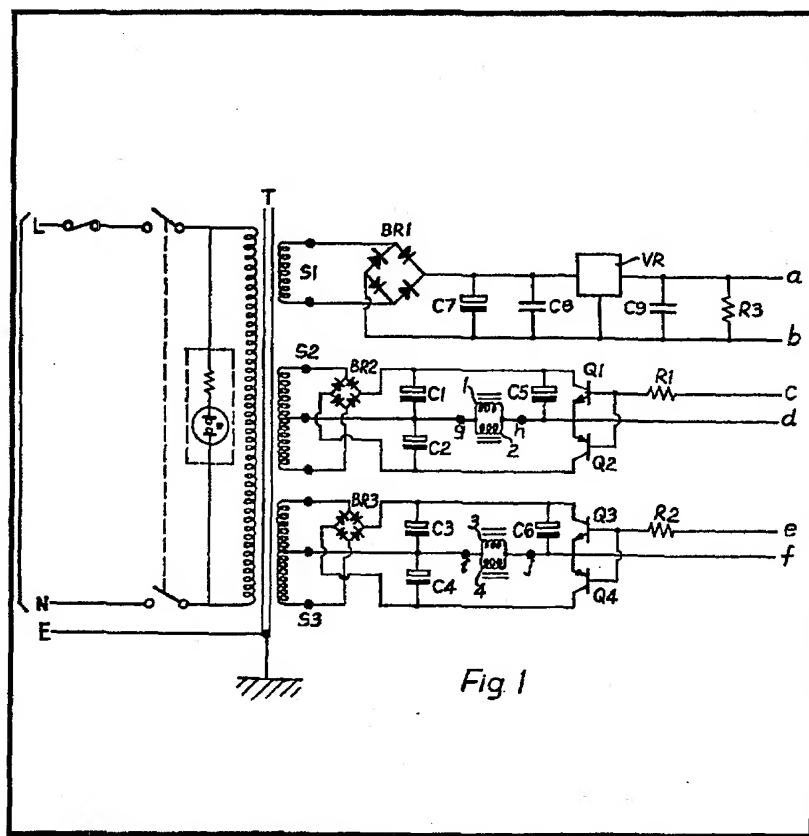


Fig. 1

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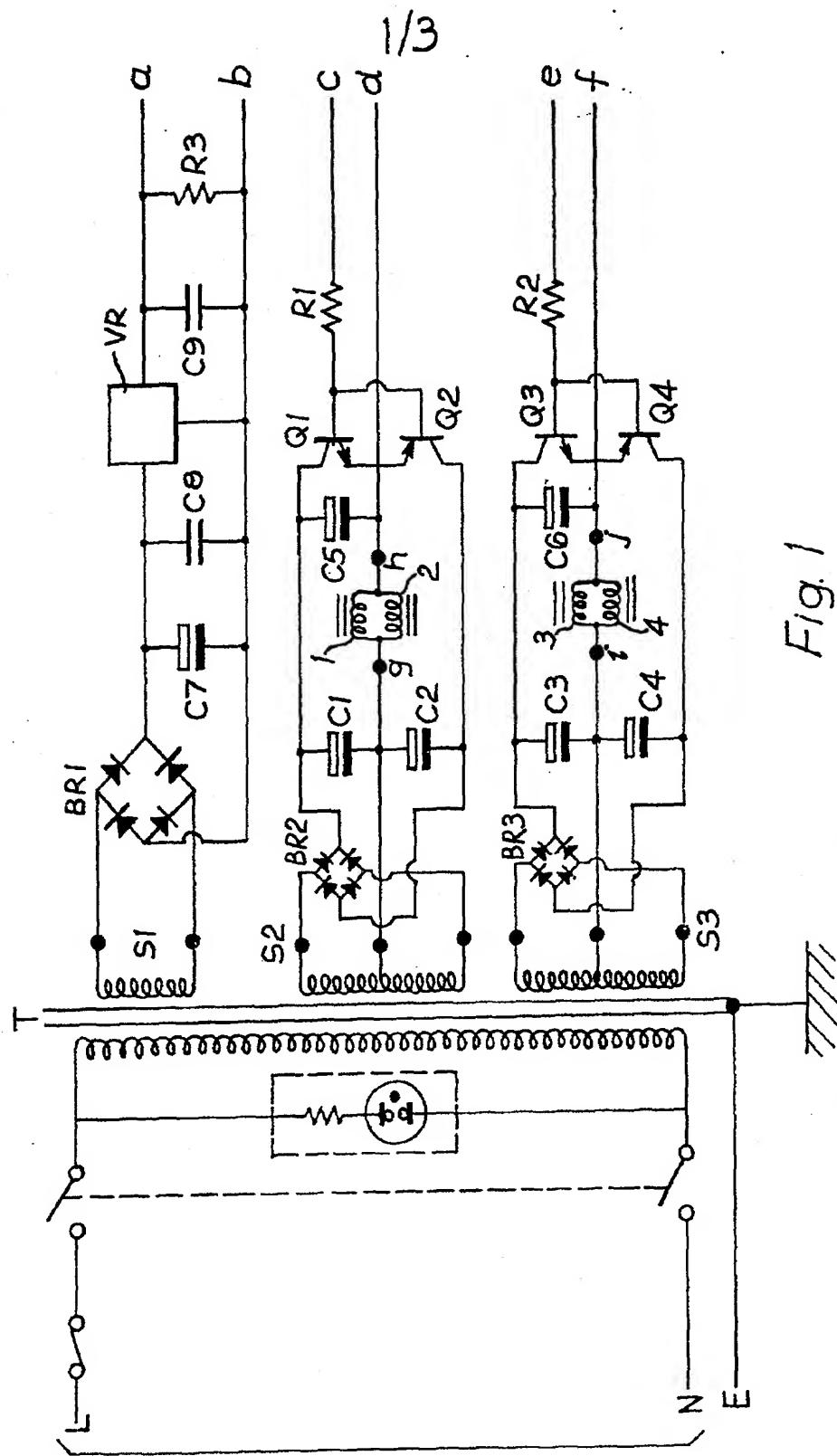


Fig. 1

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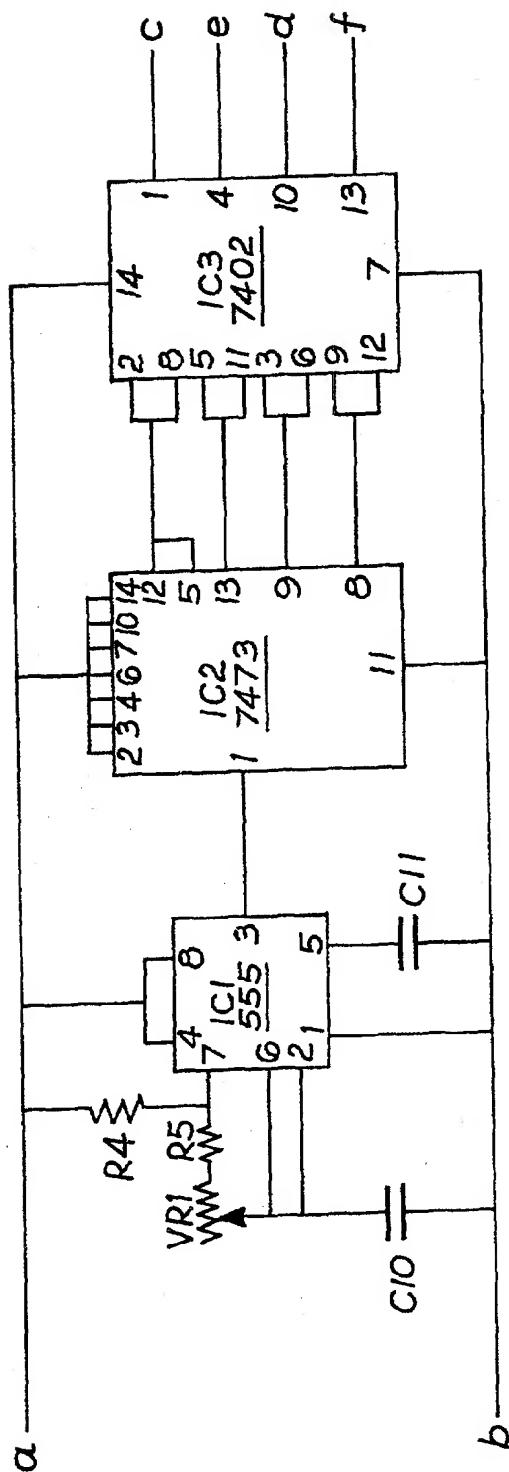


Fig. 2

7402 OUTPUTS

CLOCK IMPULSE FROM 555	PIN 1(C)	PIN 4(e)	PIN 10(d)	PIN 13(f)	TRANSISTOR SWITCHED ON ENERGISED	POLARITY
1	H	L	L	L	Q1	1+2 →
2	L	H	L	L	Q3	3+4 →
3	L	L	H	L	Q2	1+2 ←
4	L	L	L	H	Q4	3+4 ←

Fig. 3

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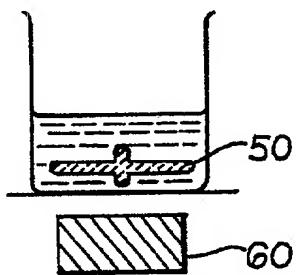


Fig. 4

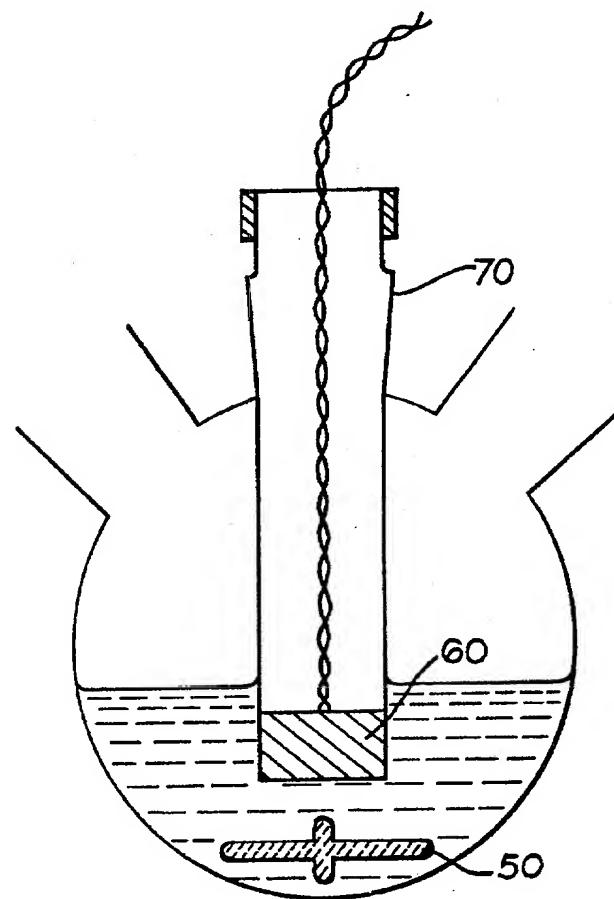


Fig. 5

SPECIFICATION

Magnetic stirrer

- 5 This invention relates to a magnetic drive arrangement for magnetic stirrers used in laboratories for stirring the contents of flasks and such like.
- Conventional magnetic stirrers in current use work on the principle of rotatably driving a magnetic follower located within a flask by means of an external magnet rotated by a drive motor. The major disadvantage with such stirrers are that the motor bearings and brushes require replacement periodically, a separator motor has to be provided for each flask to be stirred, speed control and reproducibility are poor and speed variation is restricted to a relatively limited range.
- 10 The object of the present invention is to provide an improved magnetic drive arrangement which, when embodied in a magnetic stirrer, overcomes the above mentioned drawbacks.
- 15 According to one aspect of the invention we provide a magnetic stirrer wherein the magnetic follower is driven by means of at least one electromagnet whose energisation and polarity is under the control of electronic circuit means including an electronic timer which governs the frequency of energisation of the or each electromagnet, the arrangement being such that the or each electromagnetic is supplied with current of substantially square
- 20 waveform.
- By using a commercially available solid state electronic timer (such as a 555 or ZN1034E type integrated circuit) and associated fast switching logic circuitry, the stirrer need have no moving parts other than the magnetic follower. Moreover, the timing period of such timers can be readily varied over a wide range thus affording a wide range of stirring speeds.
- 25 Preferably there are at least two electromagnets; in the presently preferred embodiment four electromagnets are employed arranged at 90° intervals with respect to the rotational axis of the follower, the electromagnets being
- 30 energised in such a way that, in effect, a rotating magnetic field is created thereby causing the follower to rotate with the magnetic field. The rotational frequency of the magnetic field is governed by the timer thus enabling the rotational speed of the follower to be varied by appropriate control of the timer.
- 35 Thus, instead of physically rotating the magnet by means of a drive motor in order to create a rotating magnetic field as in a conventional magnetic stirrer, the drive arrangement of the present invention simulates the effect of the conventional stirrer by appropriate energisation of stationary electromagnets.
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gised by D.C. supplies obtained by rectification of A.C. power and in a preferred embodiment the windings of each pair are connected in series or in parallel with each other in a

70 respective circuit including a transformer secondary winding, bridge rectifier, capacitors and semiconductor switching elements controlling the direction of current flow through the pole defining windings, said switching elements, in turn, being controlled by the timer, via logic circuitry.

In the case of a magnetic stirrer, a number of drive units (and associated followers) can be driven from common circuitry. Thus, in 80 contrast with conventional magnetic stirrers, which incorporate a drive motor and the associated power supply, a number of magnetic followers can be driven (through the agency of respective magnetic drive units) from a

85 common transformer with consequent economies. The stirrers may if desired be accommodated in a single housing, or be remote from one another.

Embodiments of the invention will now be 90 described by way of example with reference to the accompanying drawings, in which:

Figures 1 and 2 are circuit diagrams which are to be considered in conjunction with one another, the points a,b, c, d, e and f in Fig. 1 95 being connected to the corresponding points shown in Fig. 2;

Figure 3 is a logic table showing the operating states at various points in the circuit of Figs. 1 and 2;

100 *Figure 4* is a schematic view showing one form of magnetic stirrer in accordance with the invention; and

Figure 5 is a further schematic view showing another form of magnetic stirrer in accordance with the invention.

The circuitry of Figs. 1 and 2 includes four electromagnetic coils 1, 2, 3 and 4 which are disposed so as to form a four pole arrangement with the poles spaced 90° apart relative 110 to an axis about which the driven element, i.e. the magnetic follower of a stirrer, is to rotate. The coils 1, 2 are disposed on diametrically opposite sides of the axis to one another and are connected in parallel or in series between 115 terminals g and h. The coils 1, 2 are connected in two circuit paths the first circuit path containing an NPN transistor Q1 and the second circuit path containing a PNP transistor Q2. The transistors Q1 and Q2 act as

120 switches which are controlled by the inputs applied to them via terminals c and d as explained hereinafter. The coils 1 and 2 are so arranged that their polarities are always opposite to one another as seen from the

125 follower. D.C. power supplies to energise coils a and 2 are provided by secondary winding S2, bridge rectifier BR2 and capacitors C1 and C2.

Likewise, the coils 3 and 4 are disposed on 130 diametrically opposite sides of the axis to one

another and are connected in parallel or in series between terminals i and j. Similarly, the coils 3 and 4 are connected in two circuit paths respectively containing an NPN transistor Q3 and a PNP transistor Q4 and the conductive states of transistors Q3 and Q4 are controlled by the inputs supplied to them via terminals e and f as will be explained herein-after. D.C. power supplies to energise coils 3 and 4 are provided by secondary winding S3, bridge rectifier BR3 and capacitors C3 and C4. Radio/TV interference is prevented by capacitors C5 and C6.

Energisation of the coils 1 to 4 is controlled by the timer and logic circuit of Fig. 2 to which D.C. power is supplied via secondary winding S1, bridge rectifier BR1 capacitor C7 and voltage regulating network VR. Referring specifically to Fig. 2, this comprises a number of integrated circuits labelled IC1, IC2, IC3, the pins of which are connected in the manner shown. Integrated circuit IC1 is a 555 type timer, IC2 is a 7473 dual J-K flip-flop, and IC3 is a 7402 quad 2-input NOR gate circuit. Fig. 3 shows in tabular form, the conditions of the outputs (at pins 1, 4, 10 and 13) of IC3 during the course of the production of four clock pulses from the timer IC1.

Thus, in response to the first clock pulse from timer IC1, pin 1 goes "high", as a consequence, transistor Q1 is switched on and coils 1 and 2 are energised. For the sake of example, it will be assumed that at this time, coil 1 presents a north pole towards the follower and coil 2 presents a south pole. When the second clock pulse appears at the output of timer IC1, pin 1 reverts to the "low" state and pin 4 goes "high" thereby switching on transistor 3 and energising coils 3 and 4. At this time, it will be assumed that coil 3 presents a north pole and coil 4 presents a south pole. At clock pulse 3, pin 4 reverts to the "low" state and pin 10 goes "high" thereby switching on transistor Q2 and again energising coils 1 and 2 but this time with an oppositely poled current so that coil 1 presents a south pole to the follower and coil 2 presents a north pole. At clock pulse 4 pin 10 reverts to the "low" state and pin 13 goes "high" thereby transistor Q4 is switched on with consequent energisation of coils 3 and 4 and reversal of their polarities compared with the conditions prevailing at clock pulse 2. For the fifth and subsequent clock pulses, the cycle of operation tabulated in Fig. 3 is repeated.

In this way, a rotating magnetic field is produced by the coils 1 to 4 for driving the magnetic follower which may be in the form of a simple bar magnet. It will be understood that the clock pulses are produced at uniform intervals of time and the rotational frequency of the follower will therefore be governed by the clock rate of timer IC1. The clock rate is,

in turn, controllable by means of a variable resistor VR1. Thus, by appropriate adjustment of this resistor, the rotational frequency of the follower may be increased or reduced as desired. Alternatively, the capacitor C10 may be variable to change the clock rate. In the above described embodiment using four electromagnetic coils, the cycle duration is defined by four clock pulses; however, it will be understood that a greater or lesser number of coils may be used and, in this event, the number of clock pulses defining the cycle period will change accordingly. Although two pairs of electromagnetic coils are preferred when the magnetic drive is embodied in a magnetic stirrer, it is envisaged that satisfactory results may be obtained by using only one pair of coils or conceivably just one coil whose polarity is continually reversed so as to effect stirring by oscillating the follower.

A feature of the invention is that each of the electromagnets 1-4 receives substantially peak current supply throughout the period that it is "switched-on" by the associated transistors Q1-Q4. In other words, the current received rises to the maximum value immediately the electromagnet is "switched-on" and it remains at the maximum level until the electromagnet is switched-off. Thus, in effect, each electromagnet is energised with current of substantially square waveform and there is no gradual rise and fall as would occur in circumstances where the current supply is of a sinusoidal nature. It is thought that the above-mentioned square-wave type energisation of the electromagnets serves to stabilise the rotary axis of the stirrer which would otherwise tend to "dance" about.

Referring now to Fig. 4, the magnetic stirrer 105 may take a conventional form in which the follower is located within the flask or other vessel and the drive unit (which, in the present invention, comprises one or more electromagnets and associated circuitry as opposed to a motor driven magnet) is located externally of the vessel, the follower being designated by numeral 50 and the drive unit by numeral 60. Fig. 5 illustrates an alternative arrangement in which the drive unit is located above 110 the follower 50 and within the vessel, the drive unit 60 being accommodated within a tube insertable into the flask via a suitable ground glass joint 70.

Conventional magnetic stirrers frequently incorporate a so-called hotplate on which the flask can be stood, the hotplate providing heat for heating the contents of the flask. A magnetic stirrer in accordance with the invention may likewise incorporate a hotplate which 125 may be fitted externally on the top wall of the housing accommodating the electromagnetic coils and associated circuitry.

As shown in Figs. 1 and 2, the circuit components connected to terminals a, b, g, h, i 130 and j form part of the drive circuitry for one

magnetic stirrer. The same transformer and power regulating circuitry may supply power to further sets of coils and associated circuitry thus enabling a number of magnetic stirrers to be driven from the same power supply. With such an arrangement, the magnetic stirrers can all be controlled independently of one another so as to produce different stirring speeds; however, if independent control is not required then the control circuit of Fig. 2 may be common to all of the stirrers. The stirrers may, if desired, be accommodated in a single housing with appropriate stations for location of the vessels whose contents are to be stirred.

Although in the illustrated embodiment, the magnetic drive circuit is powered from the mains supply through the agency of transformer, the magnetic drive circuit may alternatively operate at full mains voltage using thyristors, triacs or such like thereby eliminating the need for a transformer. Also, in Fig. 2, TTL logic circuitry is employed but other forms of logic are equally possible, such as C-MOS.

Compared with conventional magnetic stirrers in current use, the drive arrangement described herein has a number of advantages including: no moving parts (other than the follower) which are subject to wear or failure; much wider speed range than conventional electric motors and very high speeds are attainable; precise control of speed is possible—for example to within 0.5% for the 555 type integrated circuit or to within plus or minus 0.01% for ZN1034E type integrated circuits; no stall at low speeds and no bottom limit to speed of rotation; more compact than conventional magnetic drives; the unit operates at relatively low voltages which is a safety feature; the magnetic couple obtainable with electromagnets can be far more powerful than that obtainable with permanent magnets, hence the drive arrangement described could stir very viscous mixtures totally beyond the capabilities of conventional magnetic stirrers; by employing batteries to supply the D.C. requirements, the stirrer can be made a portable unit; the coils may be energised in a 'push-pull' mode if desired, by arranging to energise coils 1 and 2 to repel the follower at the same time that coils 3 and 4 attract it, and so on through the full rotational cycle; and the power supply requirements as described may be modified or simplified if desired, by the use of such agencies as centre-tapped electromagnet coils, photo-isolators etc.

60 CLAIMS

1. A magnetic stirrer wherein the magnetic follower is driven by means of at least one electromagnet whose energisation and polarity is under the control of electronic circuit means including an electronic timer

which governs the frequency of energisation of the or each electromagnet, the arrangement being such that the or each electromagnetic is supplied with current of substantially square waveform.

2. A magnetic stirrer as claimed in Claim 1 including means for adjusting said frequency.
3. A magnetic stirrer as claimed in Claim 1 or 2 in which the or each electromagnet is energised by D.C. current through the agency of a semi-conductor switching element or elements controlled by logic circuitry including said timer.
4. A magnetic stirrer as claimed in Claim 1, 2 or 3 comprising four electromagnets arranged at 90° intervals with respect to the rotational axis of the follower, each electromagnet being paired with and simultaneously energised with the diametrically opposite electromagnet and said pairs being energised alternately or in a pull-push mode.
5. A magnetic stirrer substantially as hereinbefore described with reference to, and as shown in Figs. 1-3 or Figs. 1-3 in conjunction with Fig. 4 or 5 of the accompanying drawings.

Printed for Her Majesty's Stationery Office
by Burgess & Son (Abingdon) Ltd.—1981.
Published at The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.